Research into the effects of solar weather on the intensity of earthbound cosmic radiation.

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Prerequisites

Before we started the research, it was important for us to establish certain prerequisites for us to be able to conduct the research effectively and efficiently.

Aim

To investigate the effects of solar weather on the intensity of earthbound cosmic radiation

Hypothesis

The amount of solar activity measured will negatively correlate with the number of cosmic ray coincidences.

Explanation of hypothesis

The intensity of galactic cosmic rays measured on Earth is related to the Sun's cycle of activity, which is well known by astronomers[1]

We know that solar wind is primarily composed of positively charged protons. This is key because most primary particles of cosmic radiation are also protons. This means that if they travel near each other, electrostatic repulsion will occur and one or the other or both courses will be altered. Our hypothesis is that increases in solar wind speed and density will negatively affect the number of events we detect on Earth. Other phenomena such as coronal holes and coronal mass ejections would also, in that sense, decrease numbers of events.

Background Science

Solar Weather

Solar wind is the constant release of mainly ionised hydrogen and helium with trace amounts of other ionised elements from the sun. Most of this is deflected by the Earth's magnetosphere (the region around a body that is dominated by its magnetic field). Solar wind rarely affects us as it driven away by the Earth's magnetic field. Initial deflection occurs at the bow shock; excess particles are then deflected by the magnetosphere.

A solar flare is the release of a large amount of electromagnetic energy which can cause radio disruptions upon meeting Earth in 8 minutes, travelling at the speed of light.

Other important phenomena we will be looking at include coronal holes (high speed streams of plasma from the Sun which can possibly increase solar wind speed) and coronal mass ejections (which are giant explosions of electrified gas and plasma, in turn accelerating protons towards Earth).

Coronal Mass Ejections are vast structures of plasma and magnetic fields that are expelled from the sun into the heliosphere.

Previous Research

When we went in to this research, we knew that there would be several pieces of research already done regarding our aim. We decided to look in to these so we could establish what we should expect.

[1] Rajesh K. Mishra and Rekha Agarwal, *'Cosmic Ray Intensity during the Passage of Coronal Mass Ejections*' (2008) 38 Brazilian Journal of Physics.

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Figure 1[2] shows a visualisation of Henrik Svensmark's theory. While his research was not to find a relation between solar activity and cosmic ray intensity, this visualisation is helpful in showing that an increase in solar activity (in this case sunspots) can increase the solar-magnetic field and therefor decrease the cosmic ray intensity.

Figure 2[3] shows cosmic ray intensity and solar sunspot numbers gathered from the Germany Cosmic Ray Monitor in Kiel[4] and NOAA's National Geophysical Data Center[5], respectively. It shows a clear negative correlation between the cosmic ray count and the number of sunspots since January 1958 to January 2010 almost perfectly.

Research

The first thing we tried to do was to determine whether there is a correlation between the particle speeds of solar wind and the number of cosmic ray coincidences detected over a specific time period. We downloaded average hourly data from the detector for each day in the week and combined each day to get a data set for the week and then downloaded the average hourly solar wind data for the same period. We could then start organising the data into tables in Excel and creating graphs to look for a correlation. However, it was hard to organise the data sets with Excel as Excel has a limit of 2 million rows. We were also onlu able to download hourly data one day at a time, making it difficult and time consuming to gather data from an extended period – we tried to fix this by downloading all detector data from the period, which resulted in too much data than feasible to handle. To solve this, we developed a python script that automatically downloaded hourly data over a period and created a table in text format. We could then simply copy this in to Excel to create graphs and determine a correlation. Figure 3 shows that there is no clear correlation. Once repeated with multiple sets of data, it became clear that there was no visible correlation with our data and once further analysed we saw there was a correlation coefficient of only 0.0782171814.

Once we had realised that trying to find a visual correlation was unlilkely, we analysed time series of cosmic ray events and solar weather data using a Python script. This revealed that the correlations between number of events and the solar winds' speed and proton density are in fact very statistically significant, reaching differences of up to 10 combined standard deviations. This tells us that there is an extremely low possibility that this correlation occurred due to complete randomness and that there is more to investigate. Repetition of these tests for 3-month time periods in both 2014 and 2016 at different detectors revealed similar results which reinforces the idea that these trends did not occur due to coincidence.

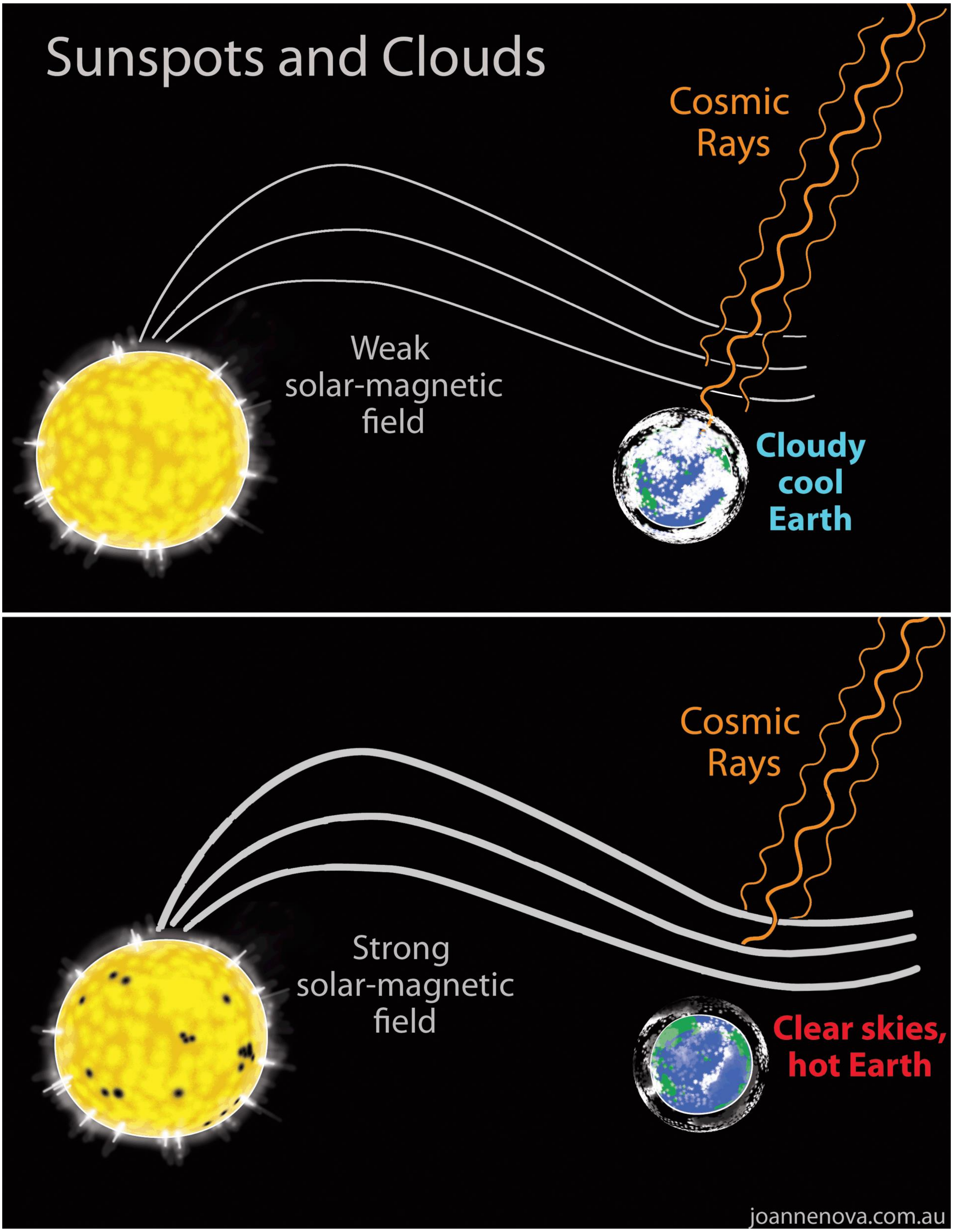
We realised that solar activity has a 11-year cycle, and we are currently at the lowest recorded solar activity, and so we decided to see if there was a more visible difference over a longer period. We analysed two sets of 8-year data. When we did this, we in fact found a slight negative correlation in our data, which supports our accepted theory.

We hope to further analyse data to attempt to conclusively prove our possible correlation

[2] Nova,J(26 Feb. 2010)."If carbon didn't warm us, what did?".[Online] *Jo Nova* .Available at: http://joannenova.com.au/2010/02/if-carbon-didnt-warm-us-what-did/
[3] Climate4you.com. (2016). climate4you Sun. [online] Available at: http://www.climate4you.com/Sun.htm
[4] http://cr0.izmiran.ru/kiel/main.htm
[5] http://www.ngdc.noaa.gov/

Appendix A - Diagrams

Fig 1 - A visualisation of Henrik Svensmark's theory



In this visualisation, a stronger magnetic field is shown by width of lines, as opposed to the convention of a greater number of lines.

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Fig 2 – Variation of cosmic ray intensity and monthly sunspot activity since 1958

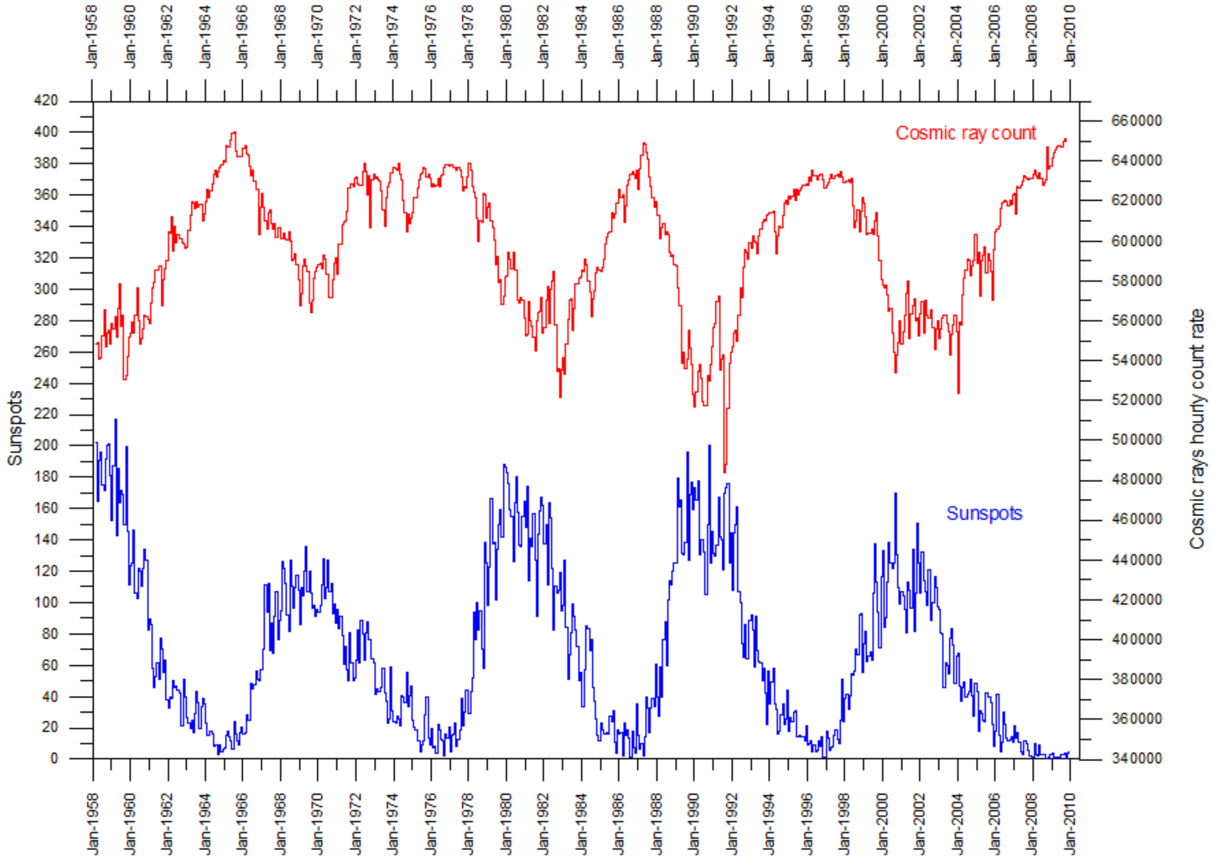
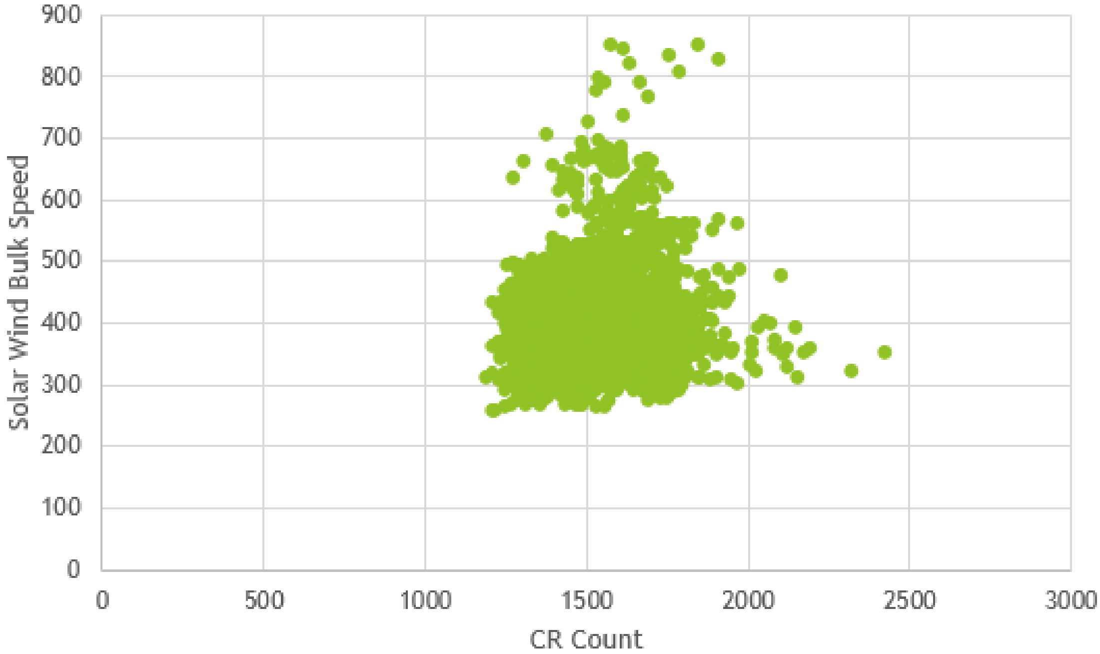


Fig 3 – Graph showing the relationship between cosmic ray count and solar wind particle speed



Appendix B – Works Cited

Rajesh K. Mishra and Rekha Agarwal, *'Cosmic Ray Intensity During The Passage Of Coronal Mass Ejections*' (2008) 38 Brazilian Journal of Physics.

Nova,J(26 Feb. 2010)."If carbon didn't warm us, what did?".[Online]*JoNova*.Available at: http://joannenova.com.au/2010/02/if-carbon-didnt-warm-us-what-did/

Climate4you.com. (2016). climate4you Sun. [online] Available at: http://www.climate4you.com/Sun.htm